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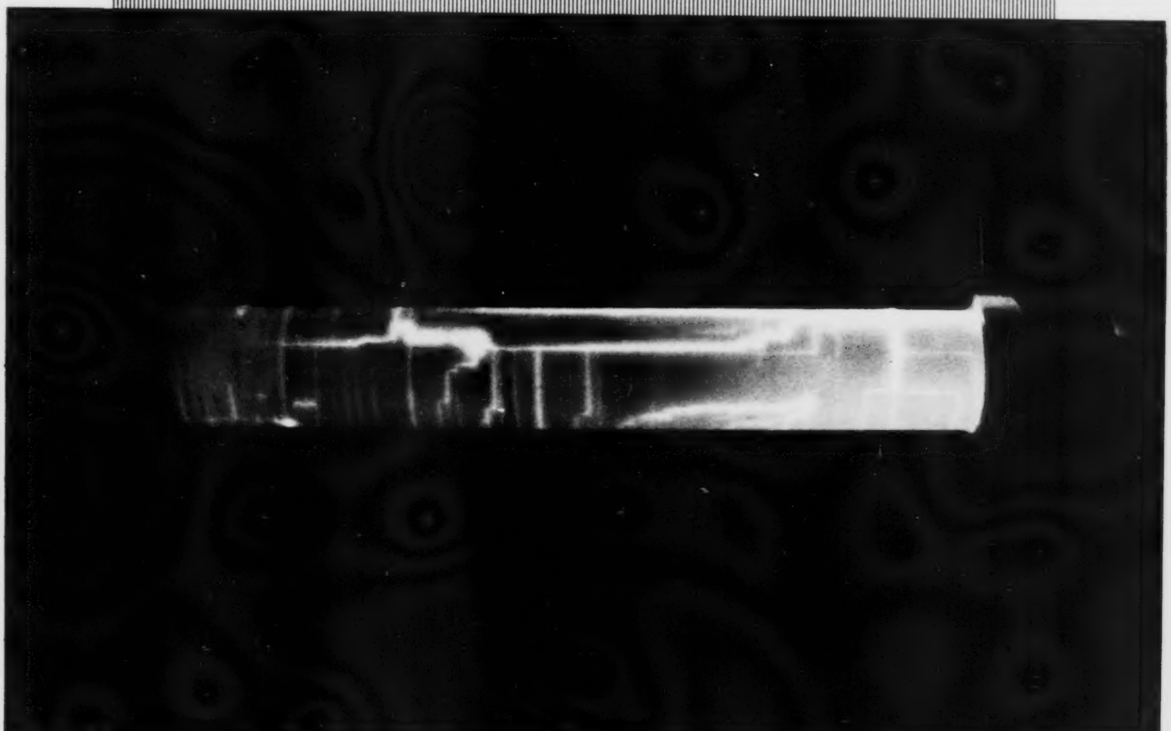
NATIONAL BUREAU OF STANDARDS

Technical News BULLETIN

VOLUME 47 | NOVEMBER 1963 | NUMBER 11



U.S. DEPARTMENT OF COMMERCE LUTHER H. HODGES, *Secretary*

NATIONAL BUREAU OF STANDARDS A. V. ASTIN, *Director*

NATIONAL BUREAU OF STANDARDS
Technical News
BULLETIN

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Subscription price: domestic, $1.50 a year; 75 cents additional for foreign mailing; single copy, 15 cents. Use of funds for printing this publication approved by the Director of the Bureau of the Budget (June 19, 1961).

Library of Congress Catalog Card Number: 25-26527

November 1963 Issued Monthly Vol. 47, No. 11

Contents

COVER: Electrical spark discharges caused by the flow of a hydrocarbon liquid through a nonconductive plastic hose. The Bureau is now conducting a study aimed at eliminating service failures in engine fuel lines caused by these discharges. Data from the study should show influence of fuel properties on generation of static electricity, the maximum rate of charge to be anticipated under operating conditions, and the proper level of tube conductivity to conduct such charges to the ground.

U.S. Metrology Team Reports on Soviet Visit

SOVIET capabilities in many areas of precision measurement are near or equal to ours. It appears possible that, with a continuation of the present relative emphasis, they may soon surpass us in some areas. This is but one point made by a team of U.S. experts who spent the month of June visiting measurement installations in and around Moscow, Leningrad, Kiev, and Kharkov in the Soviet Union, and who reported their findings at the 18th Annual Meeting of the Instrument Society of America, September 9, 1963, in Chicago, Ill.

The U.S. team, L. A. Guildner, F. K. Harris, D. P. Johnson, H. W. Lance, and A. G. McNish of NBS and G. I. Toumanoff of the Airborne Instruments Laboratory, Long Island, N.Y., and headed by W. A. Wildhack, an Associate Director of NBS, traveled to the U.S.S.R. under the terms of an agreement for the exchange of visits and information in various fields of science and technology. Their purpose: to gain familiarity with the structure and functioning of the Soviet system of precision measurements and calibration.

In general, the Americans were struck by the similarities in problems faced by both Soviet and U.S. metrologists, and by the similar methods adopted for solution of these problems. Nothing outstandingly new or novel, representing a major measurement breakthrough, was seen in the Soviet Union, and probably nothing the Soviet team will see on their return will greatly surprise them.

Despite the similarity in scientific approaches, however, the organization of Soviet metrology differs markedly from ours. In this country the National Bureau of Standards develops and maintains the national standards and carries on a broad program of research in measurement of physical quantities. NBS, however, has no regulatory functions—it provides calibration and measurement services which industry and other standards laboratories utilize at their option.

In the Soviet Union, six major national measurement research and development facilities have been established, and more are planned. These facilities, or Institutes as they are called, operate under the State Committee on Standards, Measures, and Measuring Instruments. The Mendeleev Institute at Leningrad performs much of the basic research, maintains the fundamental standards, and provides a higher level of accuracy in many fields than do the five other Institutes. In addition to verification of standards, the other Institutes have certain limited areas of research responsibility, but the Mendeleev Institute at Leningrad coordinates the technical planning.

With each of the six Institutes (located at Moscow, Leningrad, Kharkov, Sverdlosk, Kriukov, and Novosibirsk) is associated a Verification Laboratory. The Verification Laboratory in turn provides calibration services for a number of State Control Calibration Laboratories, which are responsible for lower-echelon laboratories. In total, more than 150 calibration centers are located throughout the country to provide rapid calibration services for laboratories and factories.

The Mendeleev Institute in Leningrad acts as the principal authority in this measurement chain. Test items supplied by the Institute must be calibrated within specified tolerances by lower-echelon laboratories.

While the Soviets can meet their scientific manpower needs in the calibration field through a quota system, enough students are said to apply or specialize in precision measurement to assure an adequate staff to support a growth rate of 15 to 20 percent per year. This situation is in sharp contrast to that in this country, where the selection and training of measurement personnel is a serious problem.

The American group traveled extensively while in the Soviet Union, and had the opportunity to visit government laboratories, such as the Institutes mentioned above, as well as universities and manufacturing facilities. It was felt by the group that Soviet scientists are very well qualified, and that most displayed a knowledge in depth of current world literature in their field. Many Soviet scientists can read English well enough to avoid depending on translating services. Library facilities seem excellent, and the technical training courses in the universities, especially from an equipment standpoint, are very good. The U.S. team was cordially received, and efforts were made to schedule visits, within the scope of the exchange, with scientists from organizations not on the original itinerary. Some observations pertaining to specific measurement areas are presented below.

Temperature: According to Dr. Guildner, programs are in progress to improve temperature measurements from near absolute zero to many thousands of degrees. The Mendeleev Institute maintains the International Practical Temperature Scale, measures its relation to the thermodynamic scale, and provides calibration services with accuracies comparable to those available from NBS. At the Moscow installation, a scale has been established in the range 10 to 90 °K with platinum resistance thermometers. Gas thermometry has been used to relate this scale to the Kelvin thermodynamic scale. New techniques or devices under investigation include tht acoustical thermometer, the noise thermometer, the nuclear quadrupole resonance thermometer, and photoelectric pyrometry. New standards to as high as 40,000 °C are being studied, and a technique for the measurement of radiation at 6,000 °C is under development.

Pressure: Dr. Johnson found that Soviet work with differential piston devices is quite good. Such devices, which are quite difficult to construct, utilize a piston to which pressure can be applied top or bottom, per-

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mitting the addition or subtraction of pressures above or below atmospheric. A mercurial barometer which uses interference of light to establish the height of the column was examined, as were dead-weight piston gages of various capacities. The Soviets, as we, are concerned about reference points at high pressures, and are working with melting point-pressure relationships of various solids to establish such references.

A point of interest is the very high quality machine work required to produce precision piston gages. One such gage, capable of measurements to 300,000 psi, required 90,000 psi to rotate the piston in the cylinder, an interference fit indicative of very fine tolerances. Examples of precision machine work were also seen in other laboratories. The machine shop at the Mendeleev Institute, which produces many of the instruments, operates under the apparent handicap of rather outdated machinery. That such fine work is produced in this shop shows excellent use of the talented manpower available.

Dimensional metrology: In most areas of dimensional metrology the Soviet work seems on a par with our achievements. Their optical instrumentation was of very high quality, with many variants of classical equipment being noticed which provide novel approaches to a problem. Lasers, however, are not being adapted to length measurements, as in this country, although this was an area in which the Soviet scientists expressed extreme interest. One point that was noticed by Mr. McNish, both in dimensional metrology and other measurement areas, was a tendency towards overelaboration of equipment. One example along these lines is a device for comparing four one-meter bars simultaneously with one four-meter bar, which, if built in this country, would cost about $500,000; yet this instrument is used only a few times each year. The Soviets also seemed to make less use of automatic computing facilities than do their U.S. counterparts, and statistical techniques are not widely used in the evaluation of a measurement program. Mr. McNish noted that they cannot match our present achievements in precision frequency standards. They still are working with ammonia masers, but seem to be trying to leap-frog ahead of our cesium-beam capabilities by concentrating efforts on a hydrogen maser device.

High-frequency and microwave measurements: The Soviets are putting considerable emphasis on the rapid development of measurement capabilities in the fields of high frequency and microwaves. Mr. Lance reported that, in some instances, standards work is underway over wider frequency ranges than here in this country. A few of the devices and techniques seen include:

(1) HF voltage. A slide-back vacuum-tube type of voltmeter is used from 25 mv to 100 v and frequencies from 20 kc/s to 1000 Mc/s. Accuracies to 10 kc/s are defined as $\left(0.2+\frac{0.08}{U_r}\right)$ percent, where U_r is the applied voltage. A pulse voltmeter operating on the slide-back principle has also been developed.

(2) HF power. A flow-type calorimeter for power levels from 50 mw to 10 w that has a systematic error of no more than 0.3 percent at 3 Mc/s was seen. A coaxial microcalorimeter was also displayed which is accurate to 0.1 percent + 0.2 μw up to several hundred thousand cycles per second over the range from 10 μw to 10 mw. (3) HF attenuation. The apparatus developed for attenuation measurements consists essentially of a superheterodyne receiver with a diode mixer mounted immediately adjacent to the input terminal. The apparatus covers a frequency range of 16 to 1000 Mc/s and an attenuation range of 80 or 90 db.

(4) Microwave attenuation. A reference standard rotary vane attenuator has been developed and calibrated to an accuracy of about 0.1 db for low values of attenuation and to about 0.1 percent of the attenuation for higher values. The attenuation law characteristic of this type of attenuator is not followed with sufficient accuracy to provide an absolute calibration. Instead, the attenuator is calibrated by a superheterodyne method in which the standard attenuator is of the waveguide-below-cutoff type and operates at a frequency of 60 Mc/s.

(5) Microwave noise. Microwave noise measurements can be made over the frequency range from 3,000 to 10,000 Mc/s using waveguide instrumentation in several different waveguide sizes. The accuracy of measurement was stated to be 0.2 db. A hot waveguide load operating at a temperature of 600 °C is used as the noise standard.

(6) Microwave field strength. Field-strength measurements are made using a known receiving antenna and a receiver of known sensitivity. The effective area of the receiving antenna is determined experimentally by use of the three-horn method. Waveguide horns are used at 3 cm. At 10 cm, horns with waveguide-to-coax adapters are used. The measurement accuracy achieved is approximately 5 to 9 percent.

Electrical measurements: The physical reference standards which serve as the starting point for electrical measurements in the Soviet Union are the responsibility of the Mendeleev Institute. The means by which these standards have been established and the way in which they are maintained are not different in principle from the techniques used for this purpose at NBS. The record of constancy of the electrical units in the Soviet Union is not as good as the corresponding record in the United States, a fact that is not surprising in light of the greater experience we have had in this field. Any measurement deficiencies that exist could be made up by the application of special efforts.

In some of the basic areas of electrical metrology Dr. Harris saw excellent research work, work that would compare with that of any of the other great national laboratories, and he expressed a wholesome respect for the men in charge of this work and for the university system that is training the oncoming generation of scientists. Dr. Harris feels that their electrical indicating instrument designs show a very strong German influence, and that they appear to be as capable as any group in some of the newer techniques, techniques that the American instrument industry is just beginning to consider seriously for the precision classes of instruments.

Manufacturing: It is on the assembly lines and in the reliability of finished products that the results of the measurement program are to be seen. According to Mr. Toumanoff, some of the electrical measuring instruments work at Leningrad and at Kiev seemed to be entirely equal or superior to similar work in the United States. The factory visited in Kiev specialized in laboratory types of alternating-current instruments of very high precision. Mr. Toumanoff was impressed with the care taken during manufacture, the skill and apparent high training of the operators, and especially the steps taken to insure that an instrument was stable in operation and properly calibrated before final approval. The state control laboratory at Kiev exercises inspection control on the factory calibration system, and individually recalibrates about 60 percent of the output of this factory. Many such instruments were intended for use in training persons who would eventually work in industry. Costs of Soviet-produced measuring instruments are about one-fifth those for corresponding American instruments.

NBS Director Dr. A. V. Astin, in a recent comment, set forth the significance which he attached to the U.S.–U.S.S.R. Exchange of Measurement Experts. According to Dr. Astin:

> Precision measurement technology is fundamental to the whole basis of the mass production industry, which in turn rests upon the concept of interchangeable parts. In our modern economy the interchangeable part complex is more than just interchangeability in one production plant; it involves interchangeability of components between different plants and even between different nations. Hence the concept of interchangeability rests on measurement technology.
>
> We are increasingly concerned with pressures of extending measurement capability in the most sophisticated products of our technological economy. Nowhere is the pressure to improve measurement techniques greater than in the missile industry, because such devices of extreme complexity involve hundreds of thousands of components that have to fit together and operate together, and in general these components are made within the United States and all parts of the country. Thus, the interchangeability concept must be based on a measurement system which is uniform and nationwide.
>
> Internationally, this concept of interchangeability is of very great importance. It is fundamental to the interchange of data among scientists from one nation to another. And it is also important to international trade, and, in fact, to possible cooperation between this nation and the Soviet Union in space technology. The exchange of information and the development of cooperative programs in this area will require that our measurement systems be compatible.

High-Field Cryogenic Magnet

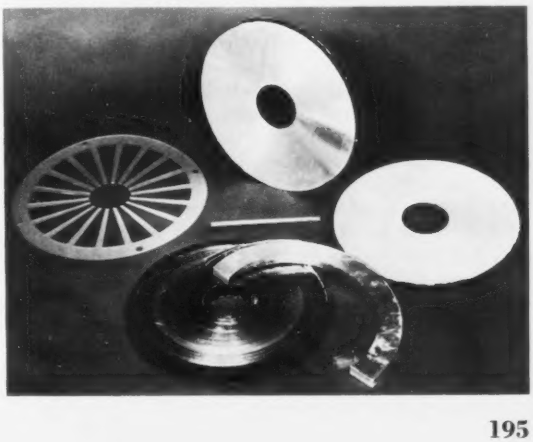
A HIGH-FIELD, aluminum-wound cryogenic magnet has recently been developed by J. R. Purcell and E. G. Payne of the NBS Boulder (Colo.) Laboratories under the sponsorship of the U.S. Atomic Energy Commission.[1] The air-core magnet produces magnetic fields as high as 70,000 gauss with a total power expenditure of 9 kw. The coil, wound from high-purity aluminum foil and cooled by liquid hydrogen, contains a cylinderical cryogenic workspace, 2.18 in. in diameter, within the magnetic field.

Magnetic fields of many thousand gauss (toy horseshoe magnets have fields of several hundred gauss) are required in such scientific applications as electron paramagnetic resonance and nuclear magnetic resonance studies, and in the solid-state maser. High-field electromagnets operating at normal temperatures have been built, but they are large and require tremendous amounts of power to produce high fields. Superconducting magnets—that is, magnets whose windings have no resistance at temperatures near absolute zero and thus require practically no power to operate—have been built in relatively small sizes and are in their early developmental stages.

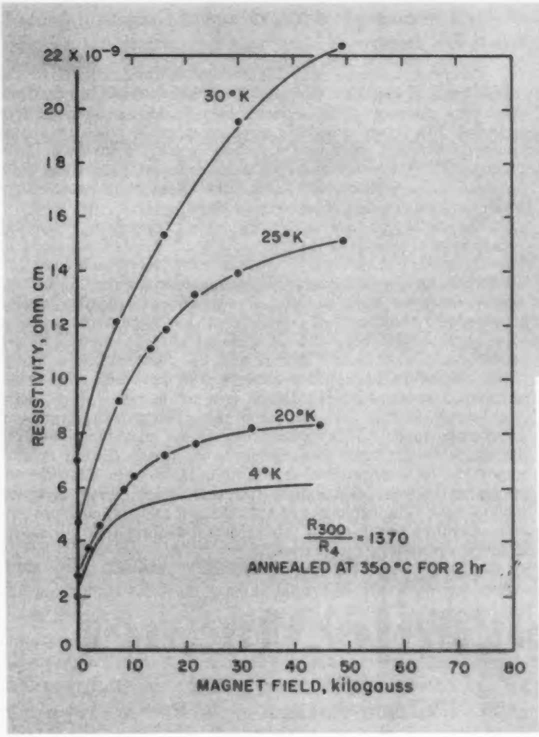
The aluminum windings on the Bureau's cryogenic magnet are not superconducting. However, their electrical resistance is approximately 1000 times lower at liquid hydrogen temperatures (20 °K) than it is at room temperature. In addition, aluminum is relatively strong, chemically inactive, and has low magnetoresistance at liquid hydrogen tempeatures,[2] thus offering some unique advantages for cryogenic windings.

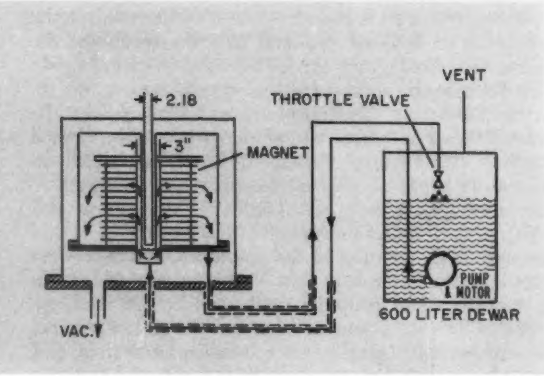
Coil Construction

Techniques employed by the electronics industry were adapted by the Bureau for building a coil of bonded aluminum foil. A long strip of aluminum foil 0.004 in. thick and 15 in. wide was rolled in a spiral with 0.00017-in.-thick capacitor paper providing insulation



Helically wound alternate layers of aluminum foil and capacitor paper form the coil of a high-field cryogenic magnet. Slabs (*center front*) were cut from the cylindrical coil, machined to a smooth surface (*center rear*), and etched with sodium hydroxide (*right*) to prevent metallic short-circuiting at the edges of the turns. Fourteen such slabs, stacked alternately with polyester separators (*left*), were connected in series by copper wires. The separators provided electrical insulation and channels for liquid hydrogen cooling medium.





Left: **Studies with aluminum foil show that its magnetoresistance at 20 °K approaches saturation near 20 kgauss. The studies also show that its magnetoresistivity is strongly temperature-oriented, and that near 20 °K its resistance is relatively low. The decrease in resistivity between 20 and 4 °K does not warrant the additional expense of maintaining liquid helium temperatures (4 °K).** *Above:* **Cryogenic magnet, showing the 2.18-in.-diam cylindrical working space within the core of the magnet. The magnet is insulated from the ambient air by means of a vacuum jacket and is cooled with 100 gpm of liquid hydrogen under pressure.**

between turns. The spiral was sawed into circular coils which were then vacuum impregnated with an epoxy resin and cured. The resulting slabs, solid and strong in construction, were machined flat to a final thickness of 0.4 in. Etching the slabs in a solution of sodium hydroxide dissolved any damaged aluminum from the foil edges, thereby eliminating metallic short-circuiting at the edges of the turns. Finally the slabs were reassembled in a stack and were separated with 0.010-in.-thick perforated sheets of a polyester resin that provided coolant passages and electrical insulation between the slabs. A total of 14 slabs, each containing 1000 turns, was connected in series to form the coil. The coil thus wound has an inside diameter of 3 in., an outside diameter of 11 in., and a total length of 5.7 in.

The assembled coil is enclosed within two concentric, stainless-steel shells each sealed to a base plate by means of highly compressed rubber O-rings and stepped flanges. The first shell contains circulating liquid hydrogen under pressure as a cooling medium. The space between the first and the second shell is evacuated to thermally isolate the cryogenic magnet from the surrounding air. Both shells incorporate concentric cylindrical projections that extend into the core of the magnet. The projection from the outer shell has a 2.18-in. inside diameter providing space for experimentation within the high field of the magnet without disassembling any part of the apparatus. The apparatus is especially well suited for low-temperature experiments, as the magnet automatically provides a 20 °K shield for the experimental region.

Cooling

To operate the magnet, the system is evacuated and purged with nitrogen and with gaseous hydrogen before admitting liquid hydrogen. One hundred gallons per minute of liquid hydrogen are pumped through the magnet to maintain the coil at 20 °K. The flow of hydrogen in the magnet is radially outward through sectorlike flow channels in the 0.010-in.-thick polyester separators. Forty-seven to 74 percent of the slab surface is exposed to the cooling medium from the inner to outer radius, respectively. The liquid hydrogen is pumped through the magnet, cooled by vaporization upon return to the storage Dewar, and recirculated.

Power

At 70 kgauss, the input power to the magnet is 7.5 kw (93 amp at 81 v), and the current density is almost 10^4 amp/cm^2. A 7.5-kva transformer with silicon power rectifiers in a full-wave bridge circuit supplies the necessary power to the coil. A variable autotransformer connected in the primary of the main power transformer controls the field. Switching the power supply in the primary circuit of the transformer allows the magnet current to decay slowly through the secondary. The power may be shut off at maximum field with no adverse effects. In addition to the magnet power requirement, the pump requires 1.5 kw (approximately 2 hp).

[1] *For further technical detail see* A high-field cryogenic aluminum-wound magnet, *by John R. Purcell and E. G. Payne, Rev. Sci. Instr.* **34,** *893 (Aug. 1963).*

[2] Transverse magnetoresistance of high purity aluminum from 4 °K to 30 °K, *by John R. Purcell and Robert B. Jacobs, Cryogenics* **3,** *109 (June 1963).*

ELLIPSOMETRY SYMPOSIUM

REPORT

MORE THAN 200 industrial, university, and government investigators who are interested in the ellipsometric method for studying surfaces and thin films attended an ellipsometry symposium at the Bureau September 5 and 6. The meeting was held to facilitate the exchange of views and information on this extremely sensitive technique for exploring unknown areas in surface chemistry and surface physics. The papers presented during the meeting, some by international authorities on ellipsometry, together with the discussions, will be published by the Bureau to provide a comprehensive treatment on the present state of the art.[1]

An ellipsometer is an optical device in which a beam of elliptically polarized light is reflected from a surface in such a way that the change in ellipticity of the light resulting from reflection can be measured. These measurements are related to the optical properties of surfaces and to the thickness and refractive index of any fiims on them. In recent years the automatic processing of ellipsometric data by means of an electronic computer has greatly simplified the use of the technique. Hence, it is being increasingly applied to investigate problems such as corrosion, adhesion of polymers, miniaturization of electronic components, and biological phenomena.

Dr. I. C. Schoonover, Deputy Director of NBS, welcomed the conferees. Dr. Elio Passaglia of the NBS polymer physics laboratory, who was chairman of the meeting, then made a few introductory remarks and explained briefly the different types of ellipsometric investigations now underway at the Bureau. He indicated that discussions on the first day would be devoted to the theory of ellipsometry, and on the second day to its applications.

Ellipsometric Theory

The first talk of the morning session was given by one of the pioneers in the field, Dr. Alexander Rothen of the Rockefeller Institute, New York City. He reviewed the historical background of ellipsometric theory, tracing it from the time of its development by Drude in 1889[2] to the present day. He explained how measurement of the ellipticity and azimuth of the electric vector of polarized light could provide the ratio of amplitudes and phase changes on reflection. He briefly outlined Drude's equations for calculating both the ellipticity and orientation of polarized light after reflection.

The next speaker was Dr. Frank L. McCrackin of the NBS polymer physics laboratory, who has set up a computer program to handle ellipsometric data. He explained his approach in establishing this program. He also described how the problem of an inhomogeneous film could be attacked, and outlined methods for computing the imaginary part of a complex refractive index value for an absorbing film whose refractive index and thickness are unknown.

Dr. Robert C. Plumb of the Polytechnic Institute, Worcester, Mass., discussed problems that may be encountered in studying very thin films by elliptically polarized light. These problems include the presence of an adsorbing layer in a dielectric at a metal-dielectric interface, sequence deposition on unoxidized metal surfaces, anomalous refractive index values, and the choice of angles of incidence for effective use of the ellipsometer.

Dr. Richard C. Smith of Melpar, Inc., Falls Church, Va., pointed out that the ellipsometric technique has an accuracy limitation which is governed by the optical apparatus, and demonstrated methods for increasing reading accuracy. He presented curves and equations to illustrate the dependence of the sensitivity of the instrument on experimental parameters.

The next speaker, Dr. J. W. Weingart of the California Institute of Technology, Pasadena, Calif., described a technique for measuring changes in the

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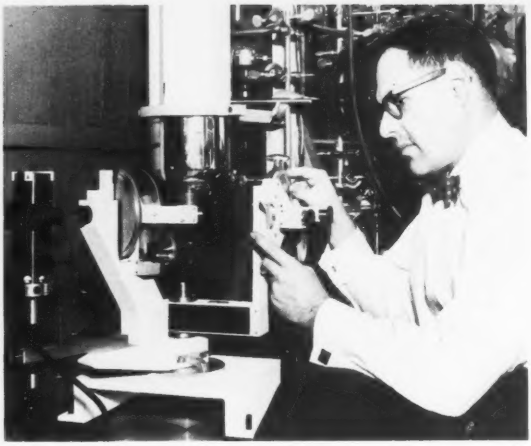
Top of page: **Scientists from industrial, university, and government laboratories attended a 2-day symposium on ellipsometry at the Bureau. Prof. F. Abelès of Paris, France, is shown addressing some of the conferees.**



Jerome Kruger demonstrates an ellipsometer used at NBS to study corrosion reactions on the surfaces of metal single crystals. The instrument was on display during the 2-day symposium.

orientation of linearly polarized light with a precision of a few seconds of arc. He explained how a similar technique could be used to measure ellipticity and orientation.

The afternoon session was opened by Prof. F. Abelès of the Institut d'Optique, Paris, France, an expert on the classical theory of physical optics. He discussed the many problems that arise when considering reflections from inhomogeneous films, and showed how the complex differential equations for such a case could be solved rigorously in some cases and only approximately in others. He said that transmission by thin films, as well as reflection, could be measured with an ellipsometer, particularly now that computer programs are available for reducing the data.

Dr. Shepard Roberts of the General Electric Research Laboratory at Schnectady, N.Y., reported that with appropriate modifications the ellipsometric technique could be applied to obtain refractive index measurements in the infrared as well as in the visible part of the spectrum. As an example of such modifications, he gave a detailed analysis of a system employing additional polarizing elements.

T. R. Young, chief of the NBS length laboratory, discussed the possibility of utilizing ellipsometry for improving length measurements of metallic end standards known as gage blocks. By carefully sliding a gaging surface of one block over the gaging surface of another block, one can "wring" them together in such a way that they offer considerable resistance to separation. However, for very precise length measurements the thickness of the wringing film between the two blocks must be considered. Mr. Young said theory indicates that ellipsometry offers an extremely sensitive means for determining wringing film thickness; he outlined experiments that are being made to verify the theory.

Dr. J. F. Dettorre of the Battelle Memorial Institute, Columbus, Ohio, concluded the first day's sessions with the description of a method which facilitates studies of oxidation phenomena now underway in his laboratory. He discussed the use of the ellipsometer with a bakeable, metal, ultra-high-vacuum system which produces evaporated films *in situ* either by resistance heating or electron-beam melting techniques. Specimen contamination is minimized by the use of ion and cryogenic pumping, and facilities are incorporated in the system to control specimen temperature from about −190 °C up to 1,000 °C. The analyses of thickness and refractive index data are accomplished by comparison of experimental values with theoretical values automatically computed.

At a banquet held the first evening for the conferees, the principal speaker was Dr. David Robinson, a member of the Office of Science and Technology in the President's Executive Office. Dr. Robinson explained the increasing impact of science on the economic growth of the country, and pointed out areas where improved liaison was needed between science and industry.

Ellipsometric Applications

Prof. A. B. Winterbottom of the Norges Tekniske Hogskole, Trondheim, Norway, who is one of the leading workers in the field, opened the second day's sessions with a talk on the present scope of ellipsometric studies. He said that the principles of applying the classic ellipsometric method remain unchanged, but that the conditions for profitable applications have greatly increased in recent years. For example, single crystal metal surfaces of a high degree of perfection can now be produced, and automatic computer facilities enable an extensive range of model formation processes to be compared with observed reflection parameter histories. Prof. Winterbottom demonstrated instrument designs which would improve present systems by providing a more rapid recording of changing phenomena.

Miss Marjorie A. Barrett of the Fysikalsk Metallurgi Institutt, Trondheim, Norway, told of work on anodic films that form on aluminum. The research was undertaken to study the effect of this type of film on the corrosion resistance of aluminum in hot water. The thicknesses of two layers caused by pore formation during anodizing, or by hydration from the hot water, were measured by combining total thicknesses. The anodic polarization necessary for the recommencement of film growth could then be determined.

Dr. Jerome Kruger of the NBS metal reactions laboratory described recent corrosion studies he has conducted by means of the ellipsometer. He said that information from studies of metal surfaces immersed in aqueous solutions can be obtained on the kinetics of growth from thickness measurements, on film breakdown or dissolution, on the growth of passive films by carrying out simultaneous electrochemical measurements, and on the properties of the films formed. Dr. Kruger also demonstrated several types of experimental cells and an ultra-high-vacuum system that he has used in his experiments.

Dr. J. V. Cathcart of the Oak Ridge National Laboratory, Oak Ridge, Tenn., reported on experiments undertaken to characterize thin oxide films on several faces of copper single crystals. He explained the influence of strain gradients in oxide films and outlined a method for qualitatively measuring such strains. He also described the effect of surface impurities on the optical properties of films, and assessed the validity of the optical models currently used as a basis for ellipsometer studies. A new X-ray technique has recently been developed at Oak Ridge, he said, for measuring films down to 20 Å thick.

The afternoon session was opened by Dr. R. J. Archer of the Bell Telephone Laboratories, Inc., Murray Hill, N.J., where research is underway on materials for electronic components. He said that ellipsometry has proven useful in determinations of the adsorption isotherms on single-crystal silicon. Measurements were made of the physical adsorption of the vapors of water and several organic liquids on variously prepared substrate surfaces, and a range of thicknesses was found. Dr. Archer explained experiments that are being undertaken to measure the chemisorption of gases on atomically clean, cleaved silicon surfaces.

In the next talk, Dr. Robert R. Stromberg of the NBS polymer physics laboratory told of recent studies of the adsorption of polymers on solid surfaces from solution. In this work, polystyrene specimens with molecular weights of 76,000 and 537,000 were adsorbed from cyclohexane on chrome surfaces, and the thicknesses and refractive indexes of the films formed were measured *in situ*. The swollen film thicknesses were 200 Å at 23 °C and 34 °C for the lower molecular weight specimens, and 500 Å or greater at 34 °C for the higher molecular weight specimens. The concentration of polymer in the film and the amount adsorbed were also determined from the measurements. Dr. Stromberg showed how multiple reflections were used to increase measurement sensitivity.

Dr. J. B. Bateman, of the U. S. Army Biological Laboratories, Fort Detrick, Md., outlined studies of thin films as an approach to the study of biological macromolecules. He showed preliminary data contrasting the properties of "intact" and "unfolded" protein molecules, and said that the values obtained were often compatible with known molecular dimensions. Dr. Bateman warned, however, that limitations arising from dispersion, anisotropy, and film heterogeneity require further examination.

Dr. L. Vroman, of the Veterans Administration Hospital, Brooklyn, N.Y., presented the next paper. He explained how he had used the ellipsometer to follow the adsorption of blood coagulation factors on various types of surfaces. The following values were found for thrombin and fibrinogen solutions: all surfaces adsorbed 35 to 60 Å of thrombin; 45 to 80 Å of fibrinogen; and 45 Å of fibrinogen on top of thrombin. This last adsorption was followed by macroscopically visible fibrin formation.

Dr. A. K. N. Reddy, of the University of Pennsylvania, Philadelphia, Pa., gave the last paper of the symposium. He reviewed recent electrochemical studies *in situ* of film formation and growth on mirror electrodes immersed in aqueous solutions, and showed how the use of an electronic potentiostat facilitated the use of the ellipsometer for these studies. When an induction time is required for film formation, he said, "chronoellipsometry" permits the investigation of anodic processes of the dissolution-precipitation type.

P. C. S. Hayfield of the Imperial Metal Industries, Ltd., Birmingham, England, and Prof. Antonin Vasicek of the Institute of Solid State Physics, J. E. Purkyue University, Brno, Czechoslovakia, who are also well-known authorities on the ellipsometric technique, were unable to attend the symposium. However, they have both submitted papers which will be included in the published proceedings of the symposium.

[1] *Upon request, information on the Symposium Proceedings will be sent as soon as the Proceedings are published. Write Dr. E. Passaglia, National Bureau of Standards, Washington, D.C. 20234.*

[2] *P. Drude, Ann. Phys.* **272,** *532 (1889); ibid.* **272,** *865 (1889); ibid.* **275,** *481 (1890).*

CRPL Consultant Writes Book

Electromagnetic Waves in Stratified Media (Pergamon Press, Ltd., Oxford, England; $15) is the most recent book by James R. Wait, consultant in radio wave propagation to the NBS Central Radio Propagation Laboratory, and Department of Commerce Gold Medal winner for distinguished authorship in the field of radio propagation.

Appearing as Volume 3 of the International Series of monographs on electromagnetic waves, this work was written primarily to be used as a reference. Although it is basically of a theoretical nature, numerous examples and references to experimental data are included. Understanding of the material requires a knowledge of electromagnetism and mathematical analysis at the undergraduate level.

Contents of the 370-page volume include: General introduction; reflection of electromagnetic waves from horizontally stratified media; reflection of electromagnetic waves from inhomogeneous media with special profiles; approximate methods for treating reflections from inhomogeneous media; propagation along a spherical surface; fundamentals of mode theory of wave propagation; characteristics of the modes for VLF propagation—theory and experiment; ELF (extremely low frequency) propagation—theory and experiment; asymptotic development for guided wave propagation; and superrefraction and the theory of tropospheric ducting. There are also indices by subject and author.

Project FIST ro
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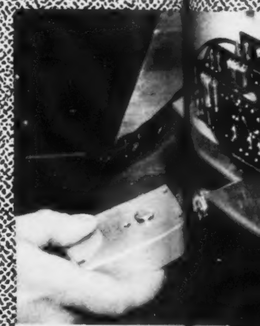
ENGINEERS at the Bureau have devised FIST (**F**ault **I**solation by **S**emi-Automatic **T**echniques), a troubleshooting system that approaches the ultimate in simplicity. Intended for use on modularized electronic equipment, this system is being developed for the Navy Bureau of Ships by Gustave Shapiro, George Rogers, and Owen Laug of the engineering electronics laboratory. It was described to key personnel concerned with equipment maintainability in government and industry at a one-day seminar held at NBS September 12, 1963. Now being applied to a naval radar equipment, the system promises, when more widely adopted, to have far-reaching consequences in training and procedures used for maintaining electronic equipment.

The amount and complexity of electronic equipment used in the military services have multiplied greatly in the past two decades, creating a need for many more skilled technicians. This, in turn, has led to continuing recruitment and training problems in the services. The resulting high cost of maintenance has increased the importance of reliability and maintainability as criteria in planning and accepting new electronic equipment.

Now being applied experimentally to a first equipment, the new troubleshooting system is expected eventually to have an impact on the maintenance of military and other high-reliability electronic equipment comparable to that resulting from modularization. The system consists of a small, hand-carried, general-purpose test instrument together with the special circuits and receptacles built in as part of the prime equipment being tested. The test instrument has a red light, a green light, a test plug on a cord, and a *self-test* receptacle; it includes four voltage comparators and logic circuitry. The operator can check tester operation at any time by plugging it into its *self-test* receptacle.

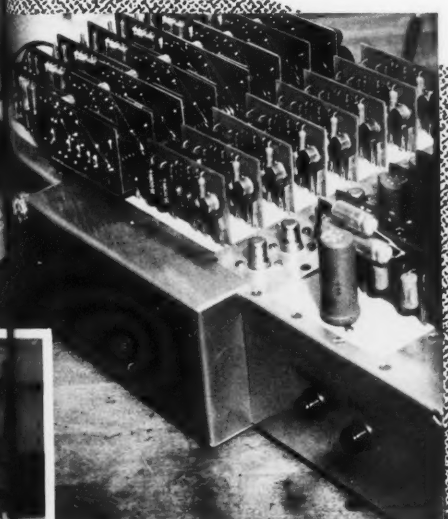
In use the test set, which occupies only a fifth of a cubic foot, gives a green (*good*) or red (*bad*) indication when plugged into each test receptable at which a test is possible. The module is within tolerance if a *good* indication is obtained. If neither indicator lights—the *no-test* response—this indicates that all needed inputs are not present at the module. The operator can test the modules in any order with a uniform, simple procedure for all types of tests. He can save some time, however, by first plugging into each group test receptacle to localize the area of failure, and then into the constituent module receptacles to find the defective module.

Circuits needed by the system to adapt module operational parameters for *good–bad* indication by the test instrument are in the prime equipment. They are being designed with subminiature components on printed circuit boards, so they can be mounted on the backs of the module test receptacles. All of these transformation networks are passive, permitting the measurement of properties such as a-c and d-c voltages, frequency, amplification, voltage waveforms, impedance, frequency response, and a variety of other electronic and physical measurements. Each transformation network operates to permit each desired operational and circuit parameter to be sensed as small voltages.



Left: **Michael Fulcomer tests module in electronic equipment by plugging in test device and observing which indicator lights up.** ***Good*** **indication shows module to be performing as specified on up to four simultaneous tests.** ***Bad*** **indicates that the module is out of tolerance and should be replaced.** *Right:* **Probe of a semiautomatic tester is inserted into its self-test receptacle.**

rovides Quick Fault Isolation



The test set operates by comparing two voltages for each test, such as the input to an amplifier module and its output. The design of the transformation network is such that it converts the amplifier input and output signals into voltages of comparable magnitude, provided that the amplification is within design tolerances. The test set comparator determines whether or not these voltages have comparable magnitudes.

The output signal is actually obtained alternately at opposite ends of one of the resistors in the attenuation network, the components of which have such values that the normal attenuated voltage is obtained at the high end of the tolerance resistor for a module of the lowest acceptable gain and at the low end for the highest-gain module acceptable. Any module of this type having a gain between the acceptable limits must produce an output signal that is greater than the ideal level when sampled at one end of the tolerance resistor and less than the ideal at the other end.

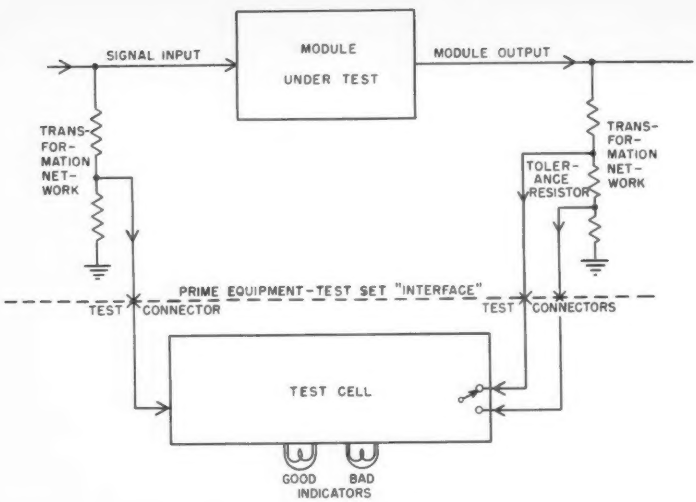
The comparator input is switched alternately between the ends of the tolerance resistor, so that its output changes polarity in testing a module characteristic within the specified limits. This makes for simplification of the circuitry and the indication. The comparator drives a zero-crossing detector circuit which operates the green (*good*) indicator light if the comparator output changes polarity and crosses zero. Failure of the comparator output to reverse polarity (indicating a module characteristic exceeding either limit) causes the detector to energize the red (*bad*) indicator.

A simple, one-cell test set would consist of two input amplifiers, identical except for one having a switch selecting its input from either end of the tolerance resistor; two peak-to-peak detectors to rectify the signals; a differential d-c amplifer to compare them; a zero-crossing detector; and logic circuits. Four such cells in each test set permit the simultaneous measurement of interacting module parameters. The test set operator needs no skill or training to identify and replace the failed module; he need know no more about electronics or the equipment being tested than the maintenance man who replaces the electric light bulbs. The technicians are called in only if the "bulb changer" is unable to find the malfunction, as in the case of faults in cabling or connector wiring.

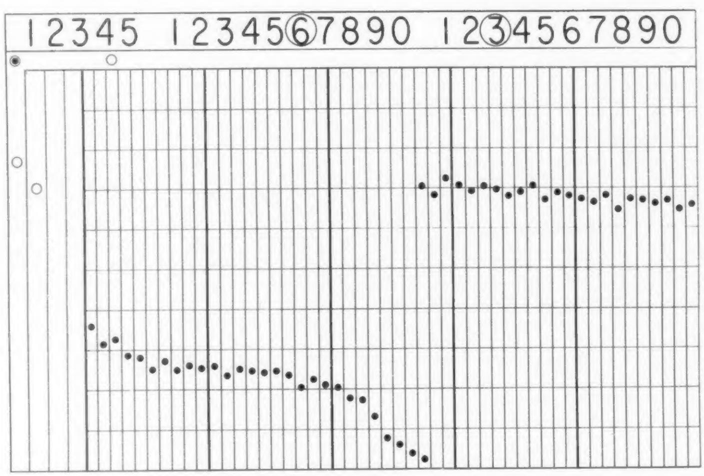
Project SAFARI

FIST design techniques not only carry on the maintenance revolution already started by modularization, but have already sired a project promising an even more radical change in maintenance. This is Project SAFARI (***S***emi-***A***utomatic ***F***ailure ***A***nticipation ***R***ecording ***I***nstrumentation), a system of measuring and recording equipment performance. SAFARI consists of a tester much like the FIST tester except that it presents performance figures in a graphical form using a device for recording and viewing module performance as a function of time.

Project SAFARI uses equipment performance measurements obtained from a test device similar to that



FIST test system uses a tester which is plugged into connectors provided in the equipment tested. No technical skill is required of the operator, since no settings or interpretations are needed to use the system. The test set compares module output with a standard voltage, frequency, or the module input by means of transformation networks. Shown is a transformation network consisting of resistors, such as could be used to test amplifier gain.



The performance of electronic modules is recorded on 35-mm film as microscopic dents, superimposed on a photographed grid in the Project SAFARI failure anticipation program. The plot of module performance shown approaches the lowest acceptable level (*bottom of chart*), at which point the module was replaced and the performance of the new module recorded, starting at a level slightly below the maximum acceptable (*top of chart*).

of FIST, but which in addition graphically plots successive measurements for comparison with an established rejection level. The rate at which the performance approaches this level can be easily monitored and the module replaced before the rejection level is reached. This procedure could add a new order of reliability to electronic equipment that is used where reliability is the greatest consideration.

The greatest impact of the FIST troubleshooting system is expected to be in alleviating the shortage of capable electronic technicians, by enabling unskilled personnel to do many of the required tasks. Secondary effects will be a higher level of dependable operation due to better maintenance, reduced numbers of technicians to be trained, and the accompanying possibility of creating a small, elite corps of technicians trained in greater depth. While not all equipment failures can be troubleshot by means of FIST, repaired by module replacement, or anticipated by SAFARI, the number of failures that respond to these techniques is expected to be sufficient to reduce greatly the burden of troubleshooting and repair now performed by technicians.

Premature Failures of Built-Up Roof Systems

A STUDY of built-up roof systems has recently been completed by William C. Cullen of the organic building materials laboratory. The object of the study, which was sponsored by the Army, Navy, and Air Force, was to determine the magnitude of temperature changes and linear movements of the roof-system components. These changes, due to solar heating and radiative cooling, have been found in field observations to be major causes for the premature failure of built-up roof systems which is costing the Nation millions of dollars annually.

Built-up roof systems are widely used in the United States and other countries on large buildings having relatively flat roofs (less than 2 in. of slope per foot) such as office buildings, warehouses, and factories. The built-up roof system consists of several layers or components. The deck is the base component upon which a waterproof layer (the membrane) is placed. A layer of insulation may be placed between the deck and the membrane. The final component, the protective surface, is then placed over the membrane.

Roof systems of this type should have a normal life expectancy of 20 or more years. However, field experience has indicated that solar heat often causes earlier failure. Such failure may take the form of blistering, especially if moisture is present in some component of the roof system. Solar heat has also been observed to cause wrinkling and buckling with resultant cracking of the membrane, as well as slippage of the membrane in roofs having a slope of 1 in. per foot or more. Solar heat has been found to accelerate chemical degradation of bitumen in the membrane, while thermal shock (rapid change in temperature) accelerates the physical deterioration of the bitumen.

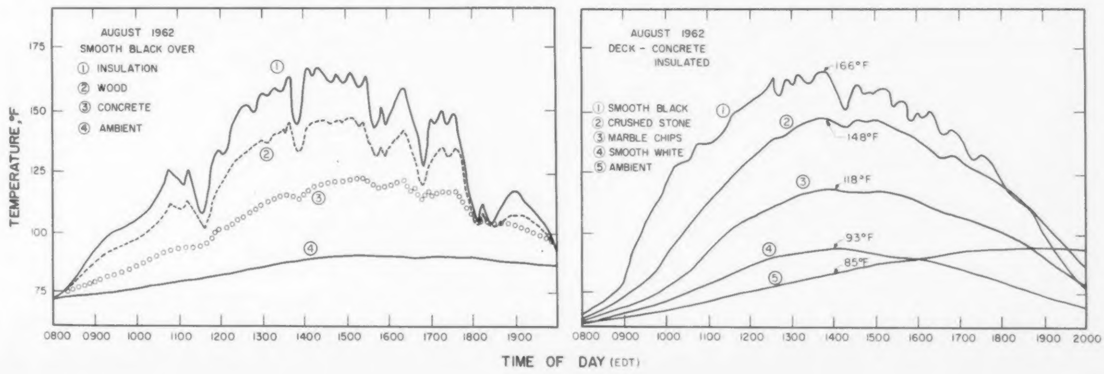
Many premature failures can be traced directly or indirectly to thermal movement within a specific component of the roof system, or to differential movement among the system components (deck, insulation, membrane, or flashings). When the coefficients of linear expansion of the components differ, the amount of movement differs, thereby causing separation of the components. This holds true for any metallic appurtenance connected to the membrane, such as flashings. In conjunction with thermal shock, thermal movement may cause splitting and membrane ruptures.

To obtain basic data that might help in preventing premature failures of roof systems, the Bureau conducted two series of tests. The first series was designed to determine the magnitude of temperature change within the membrane. The second series was set up to determine the coefficient of linear expansion of the membrane only, as the coefficients of linear expansion for most materials used in the other components were already known.

To study the degree of solar heating and radiative cooling in built-up roof systems, 20 specimens were constructed and exposed on the roof of a building at the Bureau from June 1962 to June 1963. Ten ½-in. plywood decks, 18 × 18 in., and 10 dense concrete decks, 2 × 18 × 18 in., were covered with conventional four-ply, asphalt-saturated organic felt built-up membranes, half of each group having expanded polyurethane as insulation between the deck and the membrane. One of five protective surfaces was then applied to each specimen. The surfaces used were asphalt (smooth black), crushed stone (dark grey), scoria (maroon), marble chips (white), and a polyvinyl fluoride film (smooth white). The substrates and surfaces used were selected as being representative of the extremes in materials presently used in service. Copper-constantan thermocouples were installed in each specimen between the membrane and insulation or between the membrane and deck. Temperatures were recorded continuously 24 hours a day.

Tests showed that temperature changes of roof surfaces depend upon the mass, density, and specific heat

Left: **Variations of temperature recorded during tests performed on membranes with different substrates over a 12-hr period.** *Right:* **Data obtained during tests show that the magnitude of temperature changes in a membrane is dependent upon color and texture of the protective surface.**



of the substrate; color and texture of the surface; and upon atmospheric conditions (wind velocity, rain, cloud cover, haze, etc.). The roof surface may be subcooled, i.e., roof temperature may be less than that of the ambient air because of the radiative properties of the roof system. The magnitude of the subcooling is dependent upon the mass, density, and specific heat of the substrate; upon whether the surface exposed is metallic or organic; and upon atmospheric conditions. For all practical purposes the radiative cooling of organic building material is independent of the color and texture of the surface. The temperatures of the ambient air and of all specimens were essentially the same when the specimens were covered with snow.

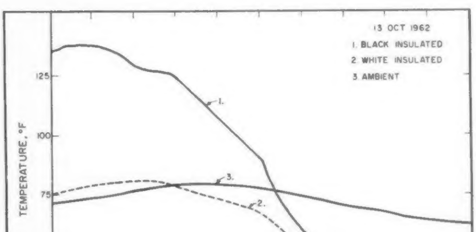
The results showed that a black, insulated roof membrane was subjected to temperature changes of about 180 °F in a 1-yr period, and in excess of 80 °F in a 2-hr period. The data regarding membranes with other surfaces showed temperature changes of lesser magnitudes. These extremes may be expected to vary in other locations.

To determine the coefficient of linear movement of the membrane (a composite material of alternating layers of bitumen and felt), the Bureau tested five sample membranes. One sample was taken from an actual roof; the others were prepared in the laboratory. The roof sample was a five-ply, asphalt-asphalt saturated organic felt. The laboratory samples consisted of four alternate layers of felt and hot bitumen. The felts used were asphalt-saturated organic felt, coal-tar pitch-saturated organic felt, asphalt-impregnated glass mat (felt), and asphalt-saturated asbestos felt.

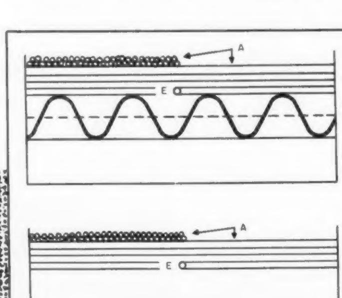
Duplicate specimens, 12×2 in., were cut from the samples. Two brass reference plugs were inserted into each specimen 10 in. apart when measured at 73 °F. Copper-constantan thermocouples were inserted into the specimens and the temperature was reduced to —60 °F. The distance between plugs was measured to the nearest ten-thousandth of an inch. A measurement was taken at every 10° rise in temperature from —60 to +160 °F.

The tests showed that the coefficient of linear expansion was not constant for any of the membranes over the range from —60 to 154 °F. This change in linear movement appears to hold for both asphalt and coal-tar pitch and for both organic and inorganic reinforcing felts.

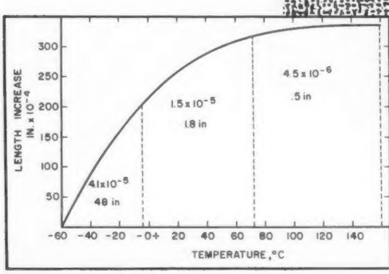
The study revealed that the expansion and contraction of the composite membrane due to changing tem-



The degree of temperature change to which a membrane is subjected depends upon the thermal reflectance of the roof surface. Data obtained show that the black-covered membrane was subjected to temperature fluctuations 2½ times greater than the white-covered membrane. The right side of the graph shows subcooling, i.e., roof temperature is less than the temperature of the ambient air. The graph shows that subcooling does not depend upon color or texture of the surface, as both surfaces recorded essentially the same temperature.

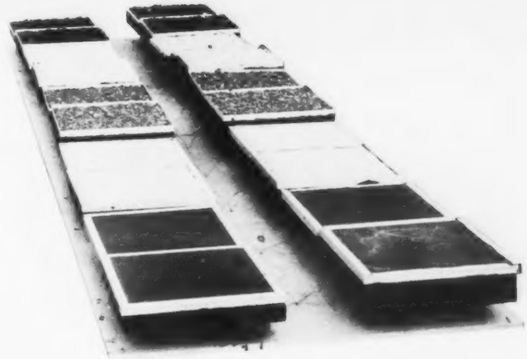


Cross sections of built-up roof systems studied show components of the systems and temperature-sensing devices used in the study. A, surface; B, membrane; C, insulation (*top specimen only*); D, deck; E, copper-constantan thermocouple.



This graph shows the changing nature of the coefficient of linear expansion of composite membranes.

The Bureau constructed 20 specimens of built-up roof specimens. These specimens were exposed to climatic conditions at the Bureau and temperatures were recorded 24 hr a day from June 1962 through June 1963.



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peratures is greater at low temperatures than that of the other components generally used in a build-up roof system. Also, the movement due to thermal changes is most critical in the low-temperature areas; the movement is minimal in the high-temperature areas. Although the magnitude of the length change was greater than expected, the changing nature of the coefficient of linear expansion can be explained theoretically, at least in part, by the viscoelastic behavior of roofing bitumens.

STANDARD MATERIALS

New Stainless Steel Standard Samples

One nitrogen-bearing and two new precipitation-hardening stainless steel standards are now available from the Bureau.[1, 2] In addition, nine other standard materials, previously available but recently out of stock, have been renewed and may be obtained from the Bureau.

New alloys for science and industry are in constant demand to fulfill specific needs. In formulating these materials and controlling the alloying processes, standards of known composition are needed. In response to requests for new stainless steel standards, the Bureau has therefore prepared, analyzed, and made available three new stainless steel alloys for controlling the composition of these materials.

One new standard stainless steel, designated NBS Standard Sample No. 343, is intended to be used for calibrating procedures for determining nitrogen. Nitrogen, introduced in definite quantities at particular temperatures into ferrous alloys, affects their strength, hardness, ductility, and other physical properties. This standard, whose composition is given in table 1, is priced at $7.50 for a 150-g unit.

Two precipitation-hardening standards, Nos. 344 and 345, are available for controlling the composition of these stainless steels. Precipitation-hardened steels, used increasingly in the aircraft and missile industry, offer a good combination of formability, strength, and corrosion resistance. Each of these standard materials is available in 150-g units at a price of $8.50; their chemical composition is given in table 1.

Of the nine renewal standards, No. 158a is a standard copper alloy; No. 3a is a standard white iron in chip form, Nos. 83c and 84g are standards of purity,

Table 1. *New stainless steel standards*

Element	Sample number		
	343	344	345
Percent	*Percent*	*Percent*	*Percent*
Carbon	0.150	0.070	0.048
Manganese		.58	.224
Phosphorous		.018	.018
Sulfur		.019	.012
Silicon		.39	.61
Copper		.11	3.45
Nickel	2.14	7.28	4.24
Chromium	15.76	14.95	16.04
Vanadium	0.036	0.040	0.042
Molybdenum		2.40	.12
Cobalt			.089
Niobium			.23
Tantalum			.002
Aluminum		1.16	
Titanium		0.076	
Nitrogen	0.074		

TABLE 2. *Renewal standards*

Sample No.	Material	Sample size	Cost
		Grams	
3a	White iron	125	$7.50
83c	Arsenious oxide	75	4.00
84g	Acid potassium phthalate	60	4.00
158a	Silicon bronze	150	10.00
371d	Sulfur	1,400	2.25
372e	Stearic acid	600	1.90
373e	Benzothiazyl-disulfide	500	2.75
378a	Oil furnace black	7,000	4.25
386d	Styrene-butadiene, type 1500	34,000	48.00

and the remaining five are rubber or rubber-compounding standards. The material, sample number, sample size, and cost of these renewal standards are listed in table 2.

As standard materials become exhausted, they are replaced by "renewal" standards as quickly as the proper grade of material can be obtained and analyzed. The composition of a renewal standard is usually not identical with that of its predecessor, but is quite similar, especially with regard to the characteristic constituent or constituents.

Renewals are indicated by the original number with an added letter to denote the relation. For example, 11a is the first, 11b the second, and 11c the third renewal of No. 11, basic open-hearth steel, 0.2 percent carbon. In this way, a particular number always represents a material of fixed or approximately fixed composition.

[1] *Standard materials available from NBS are listed in* Standard Materials, *Misc. Publ. 241, which is available for 30 cents from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. Up-to-date supplementary insert sheets to Misc. Publ. 241 list new, renewal, out of stock, and discontinued standards. This sheet, issued periodically, is available without charge directly from the National Bureau of Standards, Washington, D.C., 20234.*

[2] *Orders giving the amount, number, and name of the standard material desired should be sent to the Standard Sample Clerk, National Bureau of Standards, Washington, D.C., 20234.*

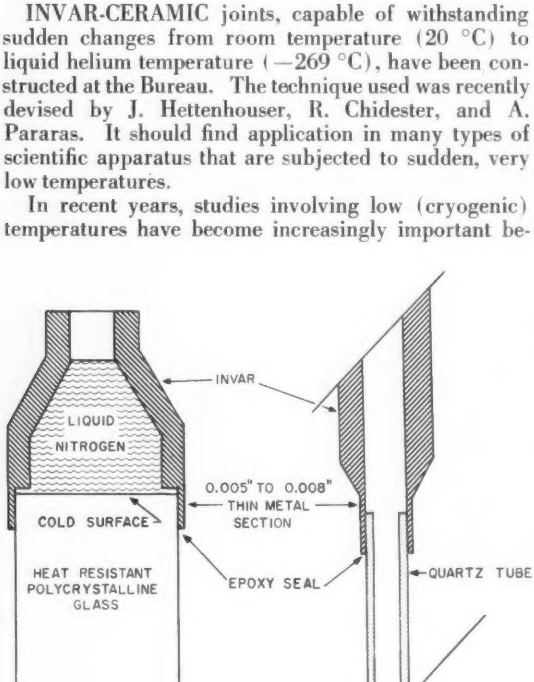
Invar-Ceramic Seal Withstands Thermal Shock

INVAR-CERAMIC joints, capable of withstanding sudden changes from room temperature (20 °C) to liquid helium temperature (−269 °C), have been constructed at the Bureau. The technique used was recently devised by J. Hettenhouser, R. Chidester, and A. Pararas. It should find application in many types of scientific apparatus that are subjected to sudden, very low temperatures.

In recent years, studies involving low (cryogenic) temperatures have become increasingly important because these conditions prevail in space, in fuels used in rocketry, and in many other applications of interest to scientists and engineers. Equipment employed in such studies frequently must be cooled gradually from room temperature to avoid fractures caused by sudden contraction; even then, costly ruptures often occur where the two materials join. In joining Invar (an iron-nickel alloy so named because its expansion coefficient is so low that its length is almost invariable) and either quartz or a polycrystalline glass with a comparatively ductile epoxy resin, the incidence of failure is substantially reduced.

Two joints of this type have successfully been made at the Bureau. In one type a hollow Invar cylinder is mated with a slightly smaller hollow quartz cylinder. In the other type, a hollow Invar cylinder is mated with a slightly smaller solid cylinder of polycrystalline glass.

In making the joints, the Invar is machined down until the wall thickness of the mating surface is reduced to 0.005 to 0.008 in. Epoxy cement is applied to the mating parts and the two materials are joined. Upon setting, preferably overnight, the joint can withstand repeated plungings from room temperature to liquid helium temperature.



Two applications of the Invar-ceramic seal. ***Left:*** **One end of a solid cylinder of a polycrystalline glass was held at liquid nitrogen temperature by means of the seal while the other end was heated.** ***Right:*** **A quartz-to-metal seal that could be immersed in liquid helium was required. These seals withstand repeated plungings from room temperature to cryogenic temperatures without failing.**

Correcting Errors in Radar Distance Measurements

Aids Air Traffic Control

NBS radio propagation physicists have evaluated causes of errors in radar distance measurements and derived correction factors for them.[1] W. B. Sweezy and B. R. Bean, of the Central Radio Propagation Laboratory at Boulder, Colo., obtained the corrections by mathematical treatment of atmospheric measurements made at air traffic control stations. Their research was sponsored by the Federal Aviation Agency (FAA) in order to obtain more accurate appraisals of distance at its air traffic control centers. The results should be of value not only for air traffic control, but also in today's military, missile research, and meteorology programs.

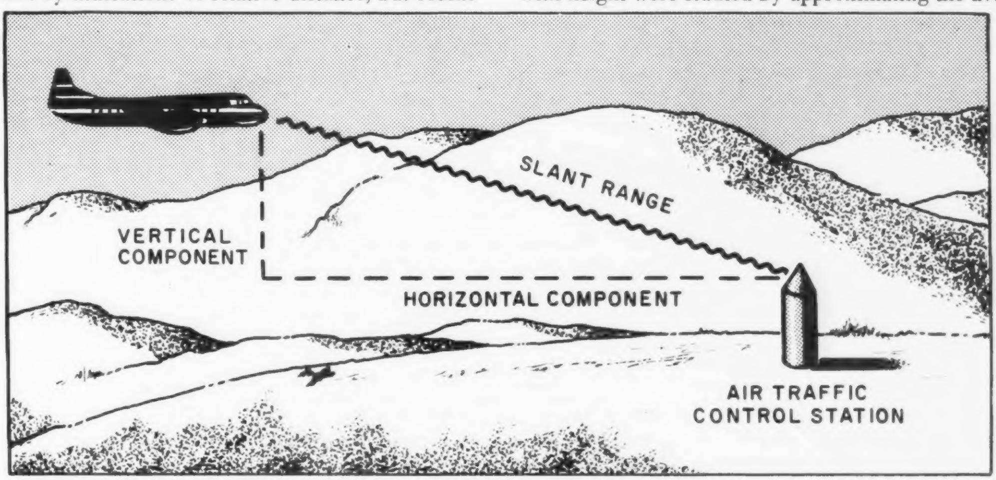
Radar sets are used at ground stations, in ships, and on aircraft to determine the position of and distance to surrounding objects and points. Distance to a radar "target" is measured by determining the time required for a pulse to travel to the target, be reflected, and return. The distance can be calculated as the product of the one-way transit time and the velocity of propagation. The transmission path is generally assumed to be straight and the velocity constant, but both actually vary with changes in the atmosphere along the path.

Today's sophisticated radar systems can present digital indications of target distance and are easily calibrated, given the rate of radio propagation to and from the target. However, radar equipments have been improved in accuracy, sensitivity, resolution, and range for years without any accompanying correction for the rate of propagation. The original requirements were met by indications of relative distance, but recent advances in technology have brought a need for absolute accuracy as well. Such accuracy for the MISTRAM baseline missile tracking system, for example, was obtained by inserting correction factors in the system's computer to account for changes in propagation rate.[2] Similar correction factors are needed in other radar systems both because of their uses (satellite tracking and aircraft position surveillance, for example) and also because of the greater absolute errors possible with the increased range of newer radars.

A radar distance measurement is usually obtained as a slant range, which is composed of horizontal and vertical components. The Bureau's study disclosed that the height error accounts for over 95 percent of the total error for most radar distance measurements (see note 1). The correction of height errors therefore will largely correct all radar distance measurement errors. The Bureau undertook to obtain such correction factors, based on normally available meteorological data, for use at FAA air traffic control stations during a wide variety of climatic conditions.

The investigators first developed a formula for determining net path refractivity. They then verified experimentally that radar height errors were correlated with changes in the computed radio refractive index along the path. The formula permits computing path refractivity as a function of atmospheric pressure, absolute temperature, and water vapor pressure as measured at the radar station. It also incorporates a reappraised value for the effective earth's radius factor.

Next the effects of changes of radio refractive index with height were studied by approximating the average



Errors in radar determination of distance are primarily those determined by the vertical component of the distance. Analysis of the radio refractive index structure of the atmosphere enabled NBS scientists to obtain radar distance correction factors for use by the Federal Aviation Agency at its air traffic control stations.

Left: **R. W. Krinks takes hygrometer readings of relativ humidity; such meteorological data are used in a for mula to compute the radio refractive index.**

refractive index gradient for different target heights. Mathematical manipulation of the value of g, the assumed gradient along the ray path, enabled the investigators to reduce greatly the height measurement error and standard deviation. They found this step to be effective when the gradient was computed as a function of the radio refractive index measured at the radar station, and more effective when the initial gradient was measured, rather than computed, by refractivity measurements at the surface and at an elevation of 1 km.

The effect of the radar path angle on range measurement accuracy was investigated for angles from horizontal to nearly vertical by analysis of radio refractiv index profiles compiled in previous Bureau studies. These profiles relate refractive index, elevation angle climatic condition, and season, making it possible t obtain factors for the modification of normal radi refractive index for known conditions of these parameters.

Finally, the variation of index with location and season was combined with the model of the path radic refractive index to obtain radar range corrections for several air traffic control stations. The corrections are for height intervals of up to 70,000 ft (21 km) for the season and local climate of the station, requiring as data the ray elevation angle and both surface and 1-km altitude refractive indexes. These corrections are effective for ground distances of up to 150 mi (241 km).

Although the greatest possible correction is obtained by use of the parameters given, excellent corrections are also obtained when the measurement of radio refractive index at 1 km above the surface is omitted. Then the initial gradient, normally determined by index measurements at the surface and 1 km altitude, is replaced by a value determined from past climatological data.[4]

[1] Correction of atmospheric refraction errors in radio height finding, by *W. B. Sweezy and B. R. Bean, J. Res. NBS* **67D** *(Radio Prop.) No. 2, 139–151 (Mar.–Apr. 1963).*

[2] CRPL aids missile tracking, *NBS Tech. News Bull.* **46,** *46 (Mar. 1962).*

[3] CRPL exponential reference atmosphere, *by B. R. Bean and G. D. Thayer, NBS Mono. 4 (Oct. 29, 1959) and* Tables for the statistical prediction of radio ray bending and elevation angle error using surface values of the refractive index, *by B. R. Bean, B. A. Cahoon, and G. D. Thayer, NBS Tech. Note No. 44 (Mar. 16, 1960). Both publications can be ordered from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402, the former for 45¢ and the latter for 50¢.*

[4] Climatic charts and data of the radio refractive index of the United States and the world, *by B. R. Bean, J. D. Horn, and A. M. Ozanich, Jr., NBS Mono. 22 (Nov. 25, 1960).*

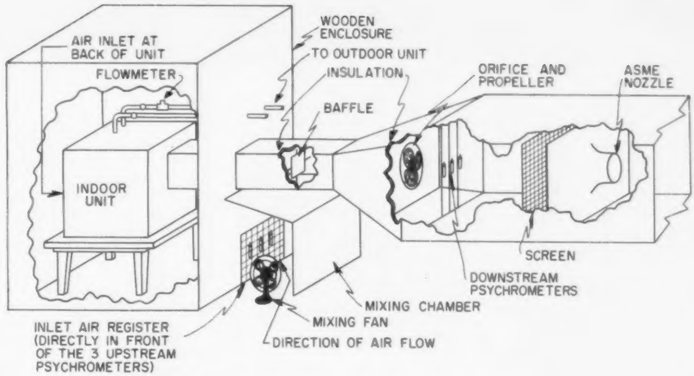
Cooling Capacity Measurements of Heat Pumps

Two Methods Compared

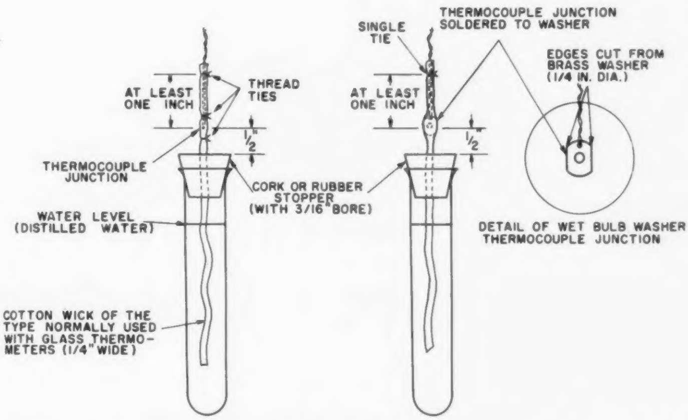
TWO METHODS of determining the cooling capacity of air conditioners or heat pumps have been compared at the Bureau.[1] The determinations were made by measuring the heat lost by cooling and dehumidifying the air flowing through the air conditioner, and the heat gained by the refrigerant. By employing careful measurement techniques and extensive calibration procedures in a series of 55 tests, J. C. Davis and P. R. Achenbach of the mechanical systems laboratory, have in 78 percent of the tests, attained agreement between the results of the two methods to within 4 percent.

Results of simultaneous cooling-capacity measurements made by the psychrometric (air flow) and refrigerant-side (refrigerant flow) methods indicate that the refrigerant-side determinations are relatively easy to make and are usually more reproducible, although not necessarily more accurate.

The Bureau determinations, aimed at reducing both psychrometric and refrigerant-side errors and correlating the results of the two methods, employed a commercial heat pump unit for making the 55 cooling tests. An analytical study of the results of these tests showed



Apparatus used for determining the cooling capacity of heat pumps. An auxiliary blower downstream from the nozzle, for overcoming pressure drop due to the mixing devices and ASME long-radius nozzle in the discharge duct, is not shown in the diagram.



Wet-bulb elements of the thermocouple psychrometers used to determine relative humidity in the heat pump cooling capacity tests. On the left is the original design, and on the right, the modified design. The modified thermocouple wet-bulb eliminates time-consuming ties that are necessary on the original design. The designs gave nearly identical results.

an agreement between the tests that was almost always within the allowable error of 6 percent[2] (see table). The literature does not report the kind of agreement that has been attained between the two test methods by other laboratories.

For the psychrometric determinations, humidity measurements were made with simple, easily-fabricated psychrometers, consisting of wet-bulb and dry-bulb thermocouple elements made of 30-gage (A.W.G.) copper–constantan wire. These psychrometers are more accurate than psychrometers employing glass thermometers at the relatively low air velocities encountered during the tests and are better suited to remote observation.

The humidity of the air was measured before and after it passed through the refrigerant coil, by two arrays of three psychrometers each. The difference in temperature of the air before and after it passed this coil was measured independently by two sets of five thermocouples, the five thermocouples of each set connected electrically in parallel. The rate of air flow through the unit was determined with a long-radius ASME nozzle (see note 2). From these measurements, the rate of heat transfer to the refrigerant from the air was calculated.

In the refrigerant-side determinations, the refrigerant temperatures and pressures were measured with copper–constantan thermocouples and Bourdon gages, respectively. A turbine-type flowmeter was used to measure the rate of flow of the refrigerant in the liquid line. From these measurements the amount of heat transfer from the air to the refrigerant was also calculated. The heat generated by the blower motor downstream from the coil was considered in the calculation.

Comparison of psychrometric and refrigerant-side capacity value for cooling tests

Selected ranges of disparity between the two values	No. of tests with higher psychrometric values	No. of tests with higher refrigerant-side values
Percent		
0 -0.99	4	6
1.0-1.99	4	10
2.0-2.99	1	11
3.0-3.99	2	5
4.0-4.99	3	6
5.0-5.99	0	1
6.0-7.00	0	2
	14	41

[1] *For information on measuring techniques and sources of error, see* "An investigation of psychrometric measurement techniques in air conditioning calorimetry," *by J. C. Davis and P. R. Achenbach, in* Humidity and Moisture, Its Measurement and Control in Science and Industry, *Reinhold Publ. Corp., New York, N.Y. (to be issued in early 1964).*

[2] *The psychrometric capacity tests were made in accordance with the American Society of Heating, Refrigerating, and Air-Conditioning Engineers Standard 16–56.*

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CRPL Ionospheric Predictions for January 1964. Three months in advance. Number 10, issued October 1963. 15 cents. Annual subscription: $1.50; 50 cents additional for foreign mailing. Available on a 1-, 2-, or 3-year subscription basis.

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Non-Periodicals

Bibliography of temperature measurement, July 1960 to December 1962, C. Halpern, NBS Mono. 27, Suppl. 1 (Sept. 13, 1963), 20 cents.

1963 Supplement, screw-thread standards for Federal services, 1957 (Parts I, II, and III), Handbook H28 (Oct. 15, 1963), 70 cents.

Methods of evaluating radiological equipment and materials, Recommendations of the International Commission on Radiological Units and Measurements, NBS Handb. 89 (Aug. 23, 1963), 35 cents. (This publication supersedes parts of H78. Handbooks 84 through 89 will completely replace H78.)

Experimental statistics, M. G. Natrella, NBS Handb. 91 (Aug. 1, 1963), $4.25.

Mean electron density variations of the quiet ionosphere, No. 11—January 1960, J. W. Wright, L. R. Wescott, and D. J. Brown, NBS Tech. Note 40-11 (Aug. 30, 1963), 40 cents.

Mutual interference between surface and satellite communication systems, W. J. Hartman and M. T. Decker, NBS Tech. Note 126 (Aug. 1, 1963), 35 cents.

Choking two-phase flow literature summary and idealized design solutions for hydrogen, nitrogen, oxygen, and refrigerants 12 and 11, R. V. Smith, NBS. Tech. Note 179 (Aug. 3, 1963), 75 cents.

Antenna beam elevation angle for control of tropospheric interference between space system earth terminals and terrestrial stations, S. G. Lutz and W. J. Hartman, NBS Tech. Note 180 (Aug. 25, 1963), 15 cents.

Computer program for ionospheric mapping by numerical methods, M. E. Hinds and W. B. Jones, NBS Tech. Note 181 (Aug. 20, 1963), 50 cents.

A note on antipodal focussing, J. R. Wait, NBS Tech. Note 182 (Aug. 20, 1963), 15 cents.

Report of the investigation of slow-flow meters for fuel oil distribution systems, D. R. Mackay, NBS Tech. Note 196 (Sept. 5, 1963), 20 cents.

Research on crystal growth and characterization at the National Bureau of Standards during the period January to June 1963, ed. by H. S. Peiser, NBS Tech. Note 197 (Sept. 23, 1963), 30 cents.

Publications in Other Journals

This column lists all publications by the NBS staff, as soon after issuance as practical. For completeness, earlier references not previously reported may be included from time to time.

Excitation of pi-electrons in polystyrene and similar polymers by 20 Kev electrons, N. Swanson and C. J. Powell, J. Chem. Phys. **39**, 630–634 (Aug. 1, 1963).

Optical observation of pressure induced transitions in polymers, A. Van Valkenburg and J. Powers, J. Appl. Phys. **34**, No. 8, 2433–2434 (Aug. 1963).

Cane sugar refining. II. Decolorization with adsorbents, V. R. Deitz and F. G. Carpenter, Cane Sugar Handb., ed. G. P. Meade, 9th edition, pp. 342–385 (John Wiley & Sons, Inc., New York, N.Y., Aug. 1963).

Klystron protection circuit, W. E. Case and N. T. Larsen, Rev. Sci. Instr. **34**, No. 7, 809–810 (July 1963).

Stable 6300 A auroral arcs in mid-latitudes, F. E. Roach and J. R. Roach, Planetary Space Sci. **11**, 523–545 (1963).

Visual observations of high pressure transitions, A. Van Valkenburg, Rev. Sci. Instr. Letter **33**, No. 12, 1462 (Dec. 1962).

Some intra-atomic correlation correction studies, M. Krauss and B. J. Ransil, J. Chem. Phys. **33**, 840 (1960).

Parable of the Fisherman, W. J. Youden, Phys. Teacher Editorial **1**, No. 3, 120–121 (Sept. 1963).

The wear of magnetic recording tape and solubility of the binder, F. Nesh, IEEE Trans. Audio **AU–11**, No. 3, 97 (May–June 1963).

Special techniques for use in sugar analysis, V. R. Deitz and F. G. Carpenter, Cane Sugar Handb., ed. G. P. Meade, 9th edition, pp. 605–619 (John Wiley & Sons, Inc., New York, N.Y., Aug. 1963).

Humidity (measurement of moisture in gas), A. Wexler, ISA Transducer Compendium, pp. 502–508 (Sept. 1963).

Convection phenomena from plants in still air, D. M. Gates and C. M. Benedict, Am. J. Botany **50**, 563–573 (July 1963).

Triboluminescence in a mercury bubbler, L. Schoen, Can. J. Phys. **38**, 967–970 (1960).

Deuterium isotope effect on glass transformation temperatures of aqueous inorganic solutions, L. C. Shepley and A. B. Bestul, J. Chem. Phys. **39**, No. 3, 680–687 (Aug. 1, 1963).

Mechanical reading of characters and recognition, M. E. Stevens (Proc. Intern. Patent Office Workshop on Information Retrieval), 125th Anniversary of the U.S. Patent Act of 1836, Pt. II, p. 205 (1962).

Band spectrum analysis of mercury hydride, T. L. Porter, J. Opt. Soc. Am. **52**, 1201 (1962).

One year trial for new voltmeter standard, C. Stansbury, Mag. Std. **34**, No. 3, 240–241 (Aug. 1963).

Pressure-density-temperature relations of freezing liquid parahydrogen to 350 atmospheres, Cryogenics **3**, No. 1, 12–15 (Mar. 1, 1963).

Publications for which a price is indicated are available by purchase from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402 (foreign postage, one-fourth additional). Reprints from outside journals and the NBS Journal of Research may often be obtained directly from the authors.

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